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RADIATION IN THE SPS

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1 INTRODUCTION

In the next few years the SPS will again accelerate and transfer intense (CNGS) and dense (LHC) proton beams. Beam losses in the SPS translate directly into activation of the machine elements with consequences on their lifetimes and performances (magnets, instrumentation…). The forecoming inclusion of the SPS into the LHC INB is also to be considered. Finally and foremost, the induced activity is of crucial importance for any human intervention on machine equipment. A review of the activity levels in the SPS in the past years is presented and some tools to be developed for monitoring and modelling are described.

2 REVIEW OF PAST YEARS

2.1 *Beams and statistics*

A summary of the beam statistics for recent years [1] (1995–1999) is shown in table 1 below.

	T1	T9	T2	T4	T6	Total
1995	1.22	12.80	1.10	1.36	3.04	20.30
1996	1.75	14.60	1.39	1.51	3.61	22.86
1997	1.03	16.60	1.14	1.85	1.00	21.62
1998	1.15	18.20	1.31	2.87	0.52	24.05
1999	1.60	0	3.53	3.93	1.91	10.97

Table 1: Beam statistics 1995–1998 in 10^{18} protons. T1 and T9 are in the West Area; T2, T4 and T6 in the North Area.

From 1995 until 1998, neutrino production for the West Area Neutrino Facility (T9) used high intensity and a Fast Resonant Extraction (FRE) in LSS6: on average 1.5×10^{17} protons on target per day, or 3×10^{19} over 200 days. In parallel a Slow Resonant Extraction to the North Area and the West Area (T1) was used with lower intensities.

In 1999, the FRE was not used and higher intensities could be sent with SRE to the North and West areas. However the total number of protons accelerated was reduced by about 55% with a total of 9.4×10^{18} protons on target.

Improvements in machine operation, such as transfer lines and injection matching, removing aperture restrictions and reduction of the natural closed orbit excursions, have improved the beam transmission through the SPS in recent years, and consequently reduced the beam losses.

2.2 *Radiation Surveys*

Activation is measured at the beginning of each long stop of the SPS, after a cool-down period of 30 hours, with a systematic recording of dose rates all around the accelerator. Dose rates are measured in the passage at a distance of about one meter away from the beam pipe and towards the inside of the ring. The longitudinal precision is of the order of one metre. This measurement gives a good estimate of the working conditions for personnel during the shutdown, but cannot give more information such as the azimuthal distribution of the activity around the vacuum chamber or more precise longitudinal localisation for which a manual survey is required.

Besides the hot spots, these surveys have helped identify regions of lower but still significant (50 to 250 μSv/h) activities. After careful analysis [2], these “warm spots” have been traced to beam losses linked to the details of the operation of the accelerator, allowing us to understand the loss mechanisms in most cases.

Good qualitative interpretation of the radiation survey is possible while extracting quantitative results requires more careful examination (*eg.* tracking equipment that has been exchanged in the machine. This systematic analysis will be done on surveys of recent years in view of characterising the specific activity of different types of extraction (FRE vs. RSE) and beam operation conditions. It can be seen already that the operation in 1999 has been leading to less activation than in previous years, a direct consequence of the reduced intensity (see fig. 1 for an example in LSS6).

2.3 *Damage to Materials*

Even when not activated the materials in the tunnel suffer from ambient radiation and beam losses and damage to materials such as change of mechanical or electrical properties or even a breakdown are seen after a certain dose has been integrated. Systematic studies have been done to characterise the thresholds of such damage, *eg.* 10^2 Gy for electronics, 10^5 to 10^6 Gy for cable insulation and 10^7 to 10^8 Gy for magnet coil insulation.

Dosimeters that can integrate over long periods are regularly installed in the accelerator tunnel [3] and are read after typically a year of operation. The doses recorded are then compared to the limits above and preventive maintenance, *eg.* exchange of cables, can be done to avoid breakdowns while operating the accelerator.

The most sensitive equipment such as the electronics, cables and motors of beam instrumentation and extraction equipment can hardly be made resistant enough and as far as possible the electronics controlling the equipment is placed outside the tunnel, at the expense of longer cables. Exchanges of equipment during the running period requires that a good level of spares be kept at hand: often the material removed is active enough that it cannot be repaired immediately. The spares situation is getting critical in some cases (extractions…) at the expense of higher doses received by the personnel who have to refurbish the equipment before completing the cool-down cycle.

2.4 Personnel Doses

The doses received by personnel (film badges and other personal dosimeters) are monitored by TIS/RP but minimizing the doses received is everybody's responsibility and CERN encourages every effort made to ensure that only doses As Low As Reasonably Achievable (ALARA) are received by its personnel [4].

As seen on figure 2 a large fraction of the dose is received during the annual winter shutdown (Q1) when maintenance activities take place in the tunnel *eg.* exchange of cables (LSS2 in Q1-1999). The dose received in the workshops is also higher than that received in the accelerator itself and is well distributed along the year corresponding to maintenance and repairs done on activated accelerator equipment. Specific interventions (*eg.* exchange of beam-dump, LSS1 in 1998) can also be seen on figure 2.

Between 1995 and 1999 a clear reduction of personnel doses has been obtained, see figure 3. Whether this comes from a cleaner operation, different procedures in the workshops and in the tunnel, installation of more robust equipment requiring less frequent interventions or simply less maintenance work being done is however still unclear without further investigation.

3 FUTURE BEAMS

In order to predict the radiation levels that could prevail in the SPS in future years, the main beams that will be transported by the accelerator are briefly presented below:

3.1 LHC

Dense beam extracted at 450 GeV using fast extraction. Total intensity of 4.1×10^{13} protons per pulse in ultimate version. Both the fast extraction and the density of the beam (smaller emittances) favour low beam losses with the LHC beam. On the other hand the high power density makes it dangerous to handle and protection of equipment is very important. Also a potential scraping scheme to ensure the low emittance requirements is a potential source of large, albeit controlled and localised, beam losses at high energy.

3.2 CNGS

Very intense beam (Refs [5] and [6]) of 4.8×10^{13} protons per pulse to achieve (200 days and 55% efficiency) a total of 4.5 to 7.6×10^{19} protons on target per year, depending on sharing with the LHC cycles. This represents 3 to 5 times the maximum number of protons on target per year for NOMAD and CHORUS. The beam will be extracted at 400 GeV (cost saving) using fast extraction which should favour smaller specific activities in the SPS and the extraction region. However the high intensity of the CNGS beam might lead to very significant levels of activation in the SPS.

3.3 Fixed Target

The fixed target programs to the North Area (NA48 and COMPASS) will continue at 400 GeV (cost saving) with low to moderate intensities: 4×10^{18} protons on target per year using Slow Resonant Extraction which has already been achieved in the past. Test beams to the West Area will also be provided at 400 GeV with very modest intensities and a Slow Resonant Extraction. The activation from these beams is expected to be reasonable and well controlled.

4 NEAR FUTURE

4.1 SPS in the LHC INB

In the near future the SPS will be part of the LHC INB. The details are being worked out at the moment but the basic perimeter is mostly finalised and will include, on the SPS side, the main ring and the injection and extraction lines up to and including the targets.

The consequences of this are very important for the SPS at large. The regulations affecting radiation and activation of machine equipment are:

- Tracking and specific storage of all equipment.
- Minimisation of production and proper disposal of all waste.
- Minimisation of personnel doses (ALARA).

5 MONITORING

5.1 Beam Losses

In order to measure beam losses, ionization chambers (6×36 in ring, 2×15 in LSS2, LSS6 and 11 in LSS1) are installed in the SPS; there are more in the transfer lines and close to the targets. They are robust devices and the electronics is located outside of the tunnel but aging of cables and a slight activation of some chambers are observed.

The chambers are read every 20 msec when the beam is present in the SPS and a fixed display is available in the control room to help tuning the machine from the point of view of beam losses and protect the machine: the beam dump is triggered above a certain threshold. The fine adjustment of this threshold and the introduction of references should allow monitoring for increased losses even if below the dump threshold.

5.2 Ambient Radiation

The same ionization chambers used with high gain during a beam-out segment can provide ambient radiation signal with a good sensitivity 1 μSv/h. This will be tried this year with a basic logging of the signals. Calibration of the signals will be done from a radiation survey before the startup.

The benefits of this system are:

- Detection a posteriori of repetitive micro losses and appearance of hot/warm spots if they are close enough to the monitors.
- For access in the SPS one can delay, not replace, the radiation survey by TIS/RP, which should prove very useful in active areas: targets, splitters, extraction.
- Help in scheduling interventions.

If this system proves useful one can envisage the installation of more dedicated chambers in strategic places.

6 MODELLING

6.1 Fit Model

The proposed system of measuring the ambient radiation from ionization chambers was used already by R. Keizer for the surveillance of the extractions. In parallel an *ad hoc* model of activation for this particular hardware was defined for a specific beam loss process and for specific materials and isotopes (decay constants).

This model proved to be useful for tuning the extraction channel by monitoring the specific activity from ionization chambers and triggering action when this activity was above the predicted value from the model. It has been abandoned since a few years: lack of interest or model too specific? It will be revisited this year for the extraction, and possibly extended to other hardware in the SPS (dump and injection?).

6.2 Activation Model

Part of the INB regulations is a zoning analysis of the machine, based on calculations and simulations of the activation processes, which requires:

- review of operational procedures and identification of the loss mechanisms,
- simulations (FLUKA) to obtain normalized activation and isotope information.
- beam loss measurements to obtain the prediction of activation.
- validation of the model with activity measurements (chambers and survey).

7 CONCLUSION

Although its still seems difficult to give clear predictions of the induced activity and ambient radiation in the SPS in future years, it seems that most of the required information is already available and the surveillance of the machine is well in place. A few points are worth keeping in mind:

- Details of operation are critical: we need tools and analysis.
- No hard limits from hardware has been seen so far, but the situation of spares is critical in some cases.
- The SPS will be part of the LHC INB.
- The cost per mSv will surely increase.

8 REFERENCES

[1] B. Desforges and A. Lasseur, “1999 SPS and LEP Machine Statistics”, SL-Note-99-051 OP

[2] R. Billen, “SPS Remanent Radiation, the Warm Spots”, presented at SPS-Days 1998.

[3] M. Tavlet *et al.*, “High Level Dosimetry results for the CERN High Energy Accelerators – Part2: SPS Complex 1997”, CERN-TIS-TE/98-08, April 1998.

[4] “Manuel de Radioprotection CERN” CERN-TIS-RP, 1996.

[5] “CNGS Design Report”, CERN 98-02

[6] “Addendum to the CNGS Design Report”, CERN-SL-99-034 EA

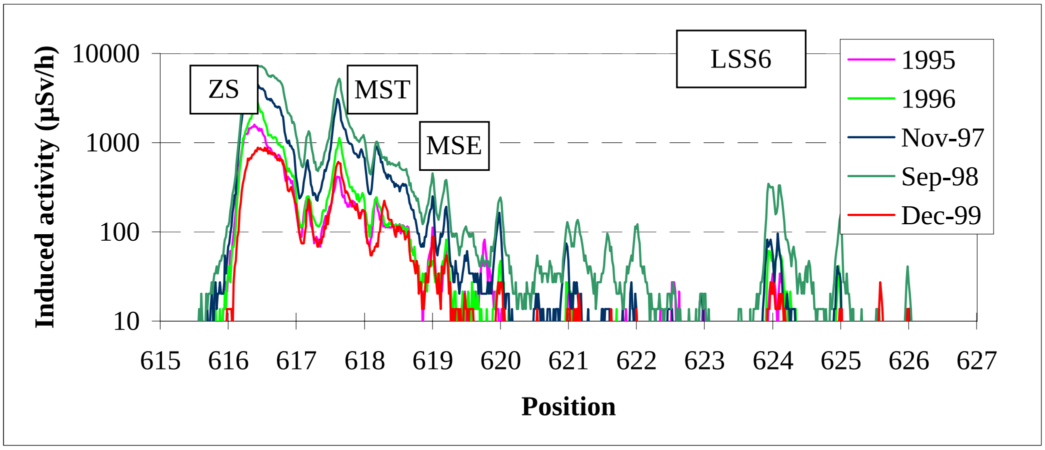

Figure 1: Comparison of radiation surveys in LSS6 between 1995 and 1999.

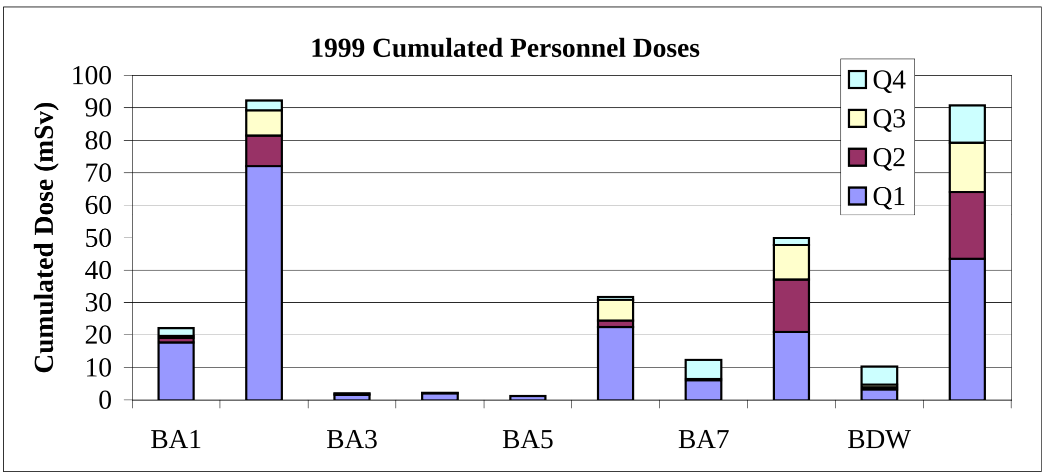

Figure 2: Personnel doses received in 1999 as a function of the quarter an area of the machine.

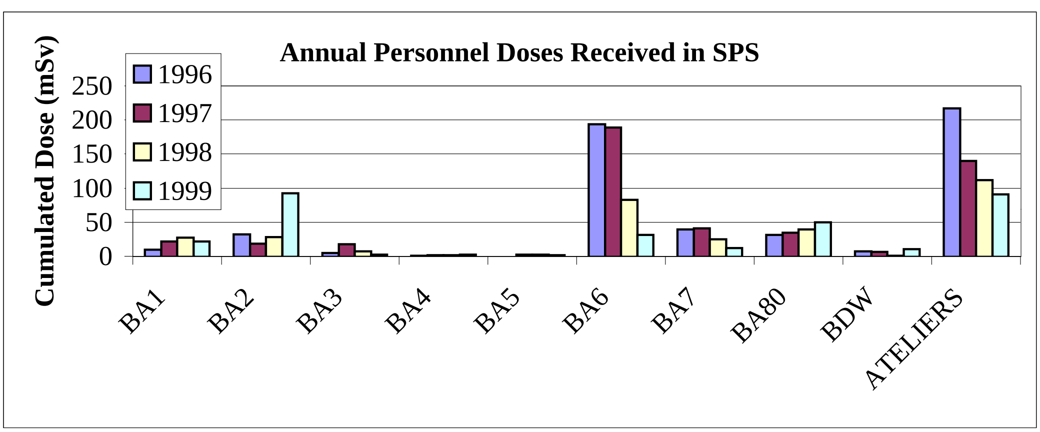

Figure 3:Comaprison of personnel doses between 1996 and 1999.